Design and Development of an Open-Architecture Robotic Lab Bench for Multidisciplinary Curriculum Integration

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Abstract

The shift toward online education has increased the need to provide remote students with learning experiences equivalent to those offered in traditional classrooms worldwide, with remote laboratories shown to maintain comparable learning outcomes [1]. Existing network laboratories often lack flexibility [2], as they are designed for single-purpose far removed simulations rather than adaptable hands-on experimentation. The development of curriculum to integrate with system architecture creates an accessible and scalable lab platform for engineering education. This lab bench uses a robotic arm that can be virtually controlled by students in an adaptive remote learning environment to perform set tasks to evaluate student understanding of robotics curriculum to improve their learning experience by confirming their analytical results with real world systems. The outcomes of this project could lead to implementation in ASU Online courses in th e area of controls, dynamics, and robotics and can be extended to other fields/applications.

Curriculum Design

Figure 1 shows the process from the student task to the teacher's evaluation. The student will use an online interface to enter information to move the robotic system to a desired spot. Data will be taken from the lab bench using cameras to send to the instructor.

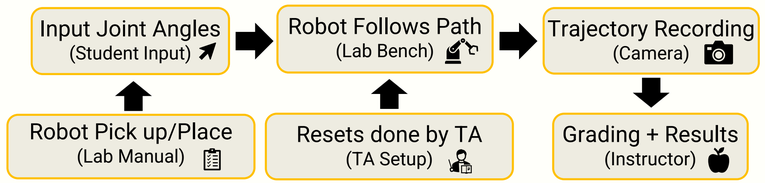

Figure 1: Workflow of an Example Experimental Module Using the Modular Lab Bench System

The CAD model for the proposed 16'' by 16'' experimental lab bench shown in Figure 2 which features modular components to adapt to the designed task.

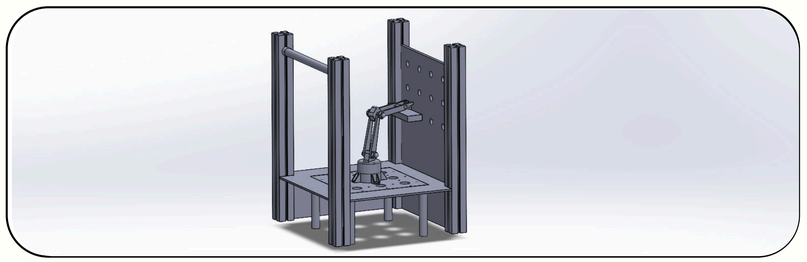

Figure 2: Experimental lab bench CAD

Lab Bench Tasks

The modular lab bench supports multiple experimental configurations, demonstrated below through two representative tasks. Figure 3 illustrates a pickup/place operation while Figure 4 demonstrates a whiteboard drawing task for trajectory planning. Together, these configurations highlight the system's ability to enable controlled interactions and adaptable experimentation within the reconfigurable workspace:

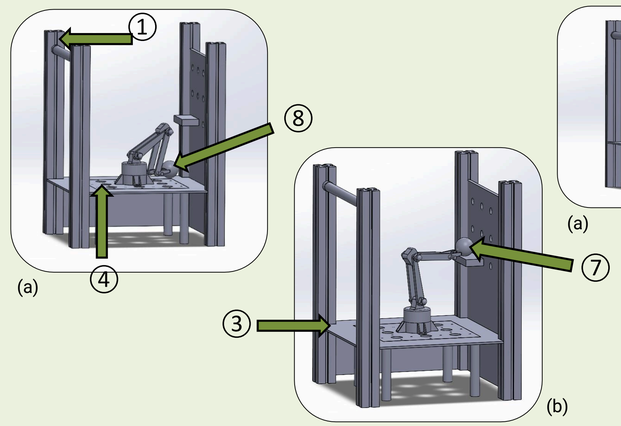

Figure 3: Pick up/Place workflow demonstration (a) Initial system configuration prior to execution (b) Final system configuration

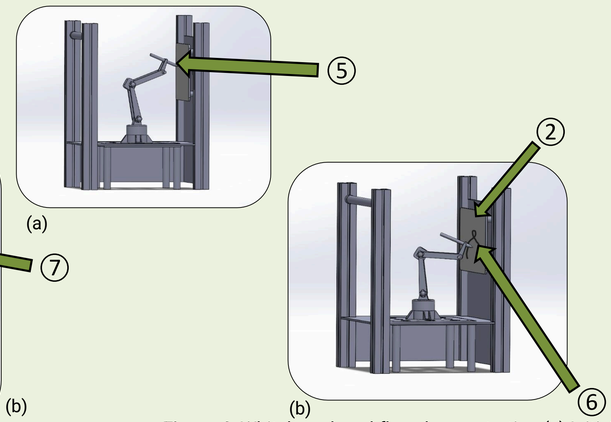

Figure 4: Whiteboard workflow demonstration (a) Initial system configuration prior to execution (b) Final system configuration

① Aluminum T-Slot frame
② Whiteboard Setup
③ Laser-cut Acrylic Base
④ Modular 3x3 Base Panel Environment
⑤ Initial end-effector position (trajectory planning)
⑥ Final end-effector position (trajectory planning)
⑦ Initial object and gripper position (pickup/place)
⑧ Final object and gripper position (pickup/place)

Fabricated System Prototypes and Experimental Setup

Figure 5: Physical prototype of the modular lab bench environment with integrated whiteboard setup

Figure 6: Physical prototype of the 3 x 3 acrylic robotic base featuring standardized mounting grid for robotic arm integration

Conclusion

The modular, open-architecture robotic lab bench was designed and prototyped to support reconfigurable experimentation in robotics and controls. A framework, driven by the curriculum, mapped learning objectives to physical system features, guiding the platform's design. The system was modeled using CAD and fabricated into a prototype using modular components to enable multiple experimental configurations

Future Work

- Integration with a reconfigurable robotic arm system.
- Development of backend software for remote access and control.
- Implementation, scaling, and testing in a course-based learning environment.

References

[1] D. Reid, J. Burridge, D. Lowe, and T. Drysdale, "Open-source remote laboratory experiments for controls Engineering Education," *International Journal of Mechanical Engineering Education*, vol. 50, no. 4, pp. 828–848, Feb. 2022. doi:10.1177/03064190221081451

[2] J. Jurc, M. Sterbak, and M. Kontsek, "Virtual Laboratories and their usage in university environment," *2020 18th International Conference on Emerging eLearning Technologies and Applications (ICETA)*, pp. 260–265, Nov. 2020. doi:10.1109/iceta51985.2020.9379179

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